Countermine Lidar UAV-based System (CLUBS)-Year 2 (extended)

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LONG-TERM GOALS

The long-term goal of this work is to examine the utility of commercial bathymetric lidar technology solely, and in combination with commercial passive imaging spectrometers, for measuring environmental information for military applications in the littoral zone. These findings will indicate how commercial systems might evolve to achieve improved performance for rapid environmental assessment and for deployment in unmanned aerial vehicles.

OBJECTIVES

1. Develop capability to produce lidar-only classification of the seafloor.

2. Develop capability to estimate underwater horizontal visibility from bathymetric lidar data.

3. Identify the best strategy for integrating a few spectral channels of passive data with lidar data for seafloor and water column characterization.

4. Assemble combined active and passive datasets over a range of environments and environmental conditions.

APPROACH

We developed physics-based methods for generating normalized waveforms and seafloor reflectance images from a calibrated bathymetric lidar. Then, we analyzed these images and waveforms, along with geometric data computed from the depth measurements, to produce lidar-only classifications of the seafloor. Subsequently, we combined lidar-derived depth, seafloor reflectance, and water column attenuation (estimated at 532 nm) to conduct constrained inversion of simultaneously-acquired passive spectral images. We then explored methods to combine the active and passive seafloor images to improve seafloor classification. We conducted field data campaigns coincident with airborne data collections to provide high-quality in situ measurements, and used these data to support algorithm development. We developed software in the IDL programming language, instantiated within the ENVI image processing environment, to sequentially process all airborne datasets and produce desired seafloor classifications and accuracy assessments.

1. REPORT DATE **2008**	2. REPORT TYPE	3. DATES COVERED **00-00-2008 to 00-00-2008**	
4. TITLE AND SUBTITLE **Countermine Lidar UAV-based System (CLUBS)-Year 2 (extended)**		5a. CONTRACT NUMBER	
		5b. GRANT NUMBER	
		5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)		5d. PROJECT NUMBER	
		5e. TASK NUMBER	
		5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Optech International,7225 Stennis Airport Drive, Suite 400,Kiln,MS,39556**		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)	
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**			
13. SUPPLEMENTARY NOTES			
14. ABSTRACT			
15. SUBJECT TERMS			

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT **Same as Report (SAR)**	18. NUMBER OF PAGES **7**	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**			

WORK COMPLETED

Our anticipated third year for this project was not funded. Therefore, the work discussed herein was completed under a no-cost-extension of year-2 funding between October 1, 2007, and March 31, 2008.

We accomplished the following work during this period:

- We refined the SHOALS seafloor imaging and classification algorithms by adding the capability to image in very shallow water.

- We tested the SHOALS-only, pixel-level classification algorithms on the Great Lakes dataset

- We developed new algorithms to accomplish a blob-level, data fusion-based seafloor classification employing a Dempster-Shafer decision algorithm. This approach implements separate classifications of the seafloor from the SHOALS and CASI data, and then combines blobs (or segments) from the two sensors into common blobs.

- We developed an organizational structure for the airborne and insitu data for the three datasets used in the project to facilitate distribution of the data to other researchers.

- We refined the functionality and menu structure of the Rapid Environmental Assessment (REA) Processor, and made the software more robust.

- We delivered the REA Processor and CLUBS datasets to the U.S. Navy and conducted a one-day training class on use of REA at our offices in Kiln, Mississippi, on March 4, 2008.

RESULTS

The addition of shallow-water imaging capability, developed in this reporting period, into the SHOALS seafloor reflectance algoithms makes it possible to generate seamless topo/bathy images from the lidar data.

We illustrate this capability in Figure 1. Here, we show a part of the "south block" dataset off the coast of Flort Lauderdale, FL. This image was created by estimating reflectance at 532nm from each pusle of the lidar, and then creating a raster image with 3m pixels. The beach is on the left side, and the right side shows an offshore spur and groove reef in about 35m of depth. The prominent linear future running left to right is a sewer outfall pipe.

The land/water interface is clearly visible in this image, and this is an innovation for both REA and the SHOALS technology. This shallow water performance was accomplished by reducing the depth accuracy requirements in the depth extraction algorithm and by extrapolating the system attenuation of the SHOALS system from deeper waters onto the beach. For this reason, the image in very shallow waters is more properly pseudoreflectance, rather than reflectance. However, these images are clearly useful for mapping, classification, and target detection purposes.
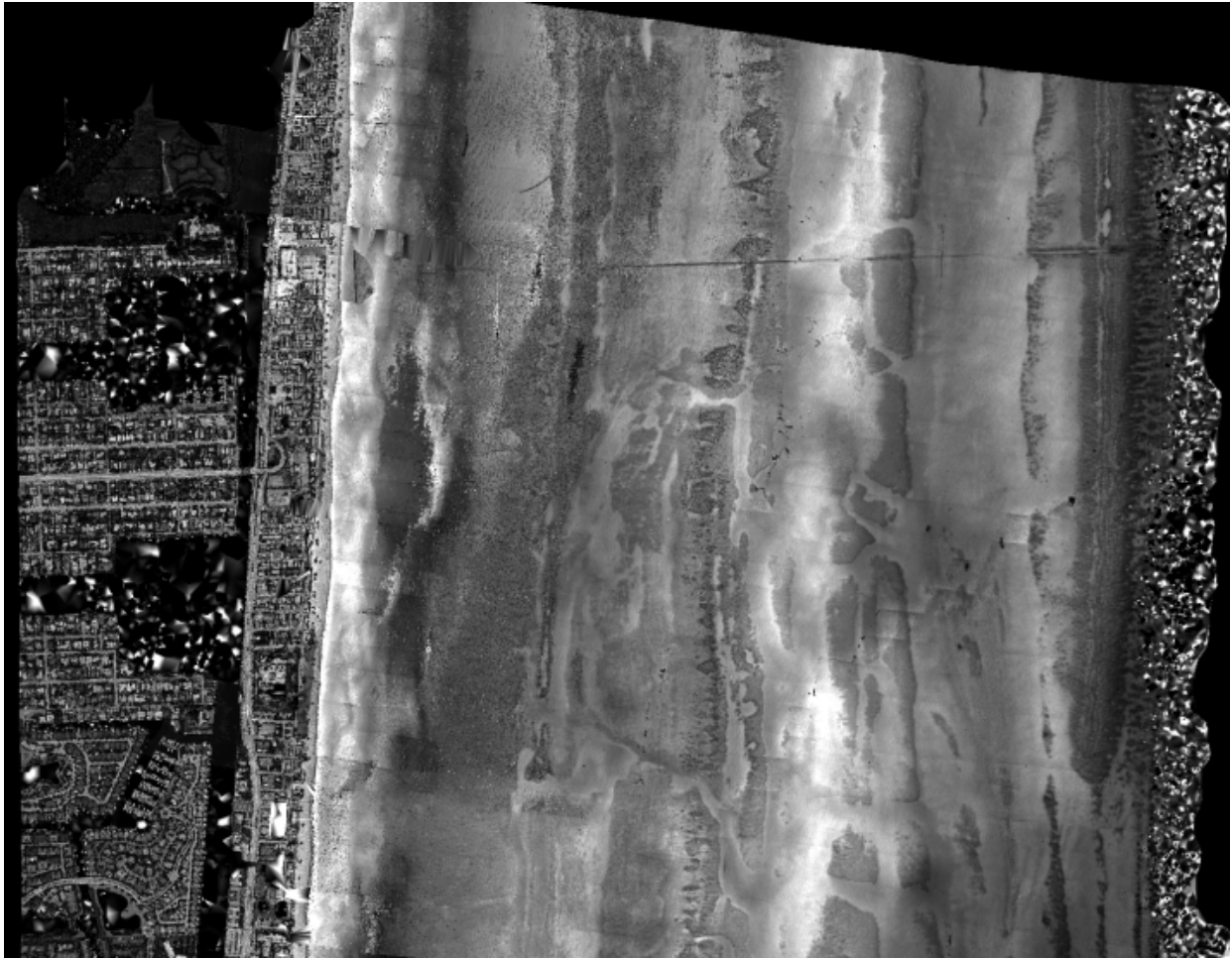
Figure 1. Continuous Topo/Bathy Reflectance (532nm) Image Generated with SHOALS data

In August 2007, we collected airborne and insitu data in Lake Huron. During this reporting period, we used the SHOALS-only classification procedures implemented in the REA processor to create seafloor classification of these data. We show these results in Figure 2. The left image is the seafloor reflectance image from SHOALS. The right image is a classification map created using SHOALS reflectance, texture metrics, and rugosity metrics extracted from the SHOALS data.

We did not have sufficient time to conduct an accuracy assessment of this classification. However, on inspection the classification looks very good, and comparison to the photographs taken by divers while collecting seafloor spectral reflectance indicates good agreement at those locations.

We did complete an accuracy analysis of the SHOALS-only classification of the Fort Lauderdale data. In Figure 3, we show a seafloor classification produced using 5 information features extracted from the SHOALS reflectance and depth data, and a nearest neighbor classification algorithm. The classes are: hardbottom, linear reef, spur and groove reef, and sand. The overall accuracy of this classification was 88% compared to an independent visual classification produced by personnel at NOVA SE University. In Figure 3, we show the classification on the left, and the ground truth on the right.
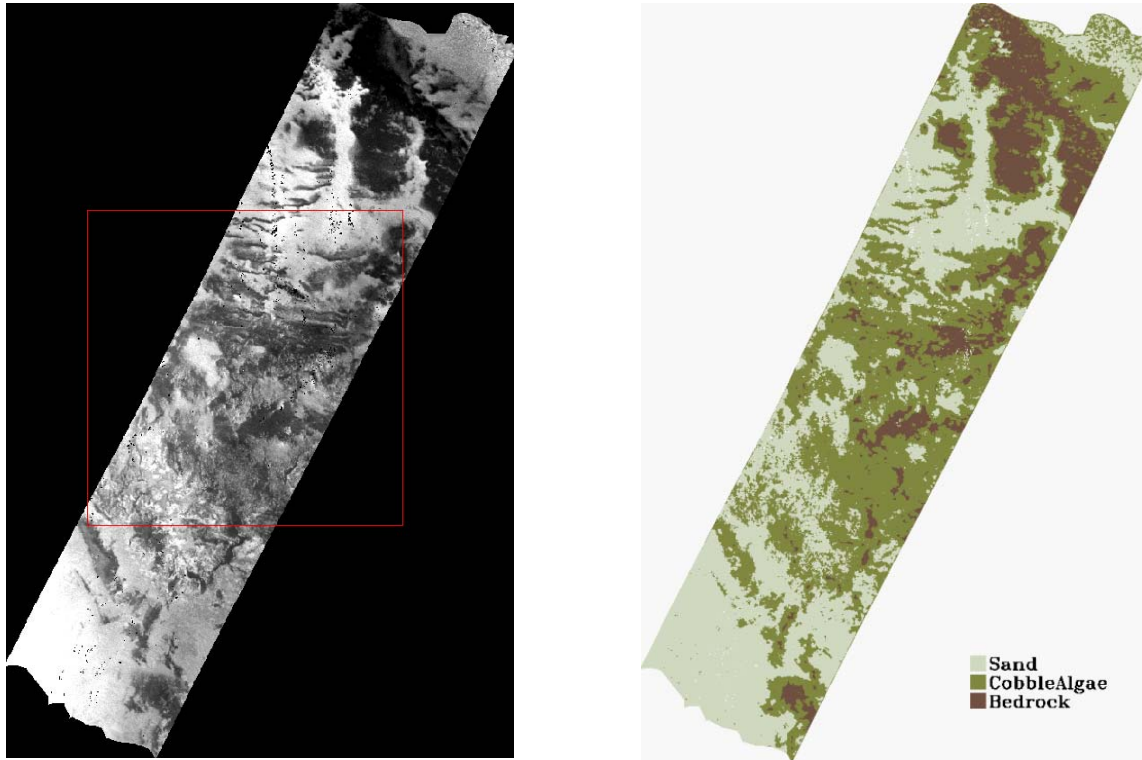
Figure 2. SHOALS seafloor reflectance (left) and SHOALS-only seafloor classification (right) of the Lake Huron dataset.
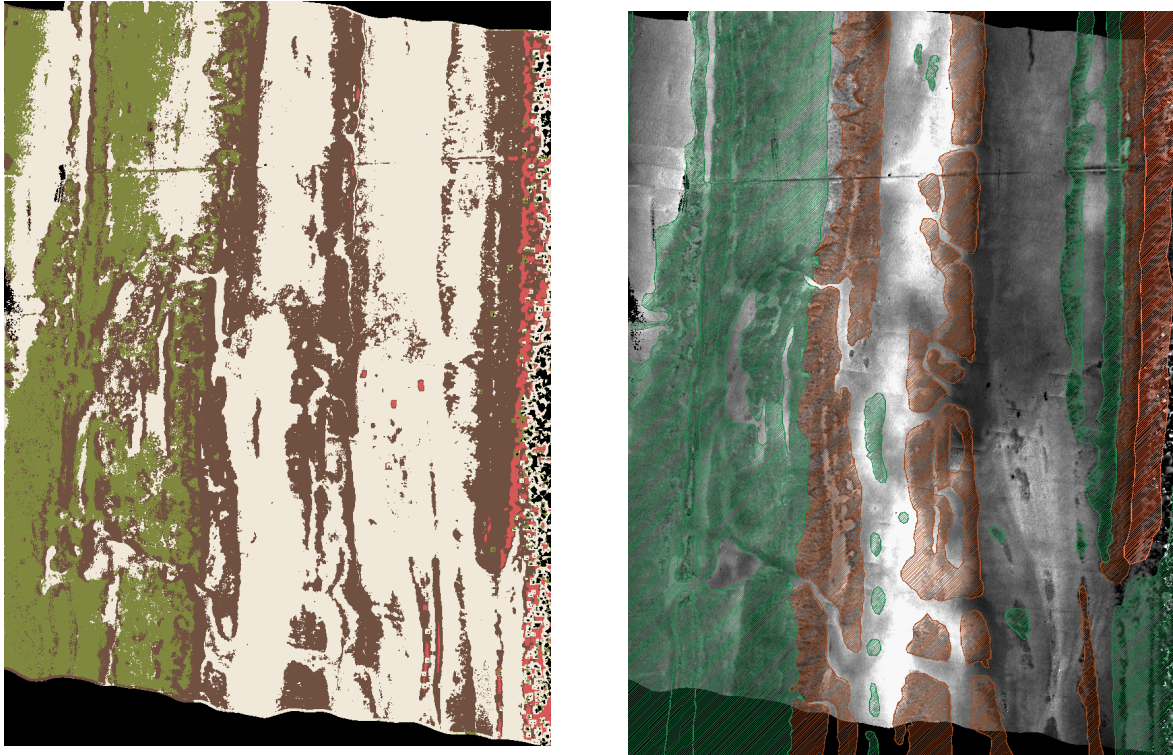
***Figure 3. SHOALS seafloor classification (left) of South Block dataset,
and ground truth (overlayed on seafloor reflectance image) right.***

One goal of the project was to investigate ways to combine active and passive data to accomplish rapid environmental assessment. During this period, we developed a procedure to accomplish seafloor classification using a high-level data fusion technique. In it, we separately produce a maximum likelyhood classification (MLC) of the SHOALS data and CASI data, and use the probabilities generated by the MLC classifier as apriori probabilities for a Dempster Shafer decision algorithm. We also developed techniques to accomplish the final classification at the blob level, through the use of set theortic methods to combine the blobs from the two individual classifications.

We illustrate this procedure for the Lake Huron data in Figure 4. Here, we show the MLC classification for the SHOALS data (left), CASI data (center), and final blob-level fusion (right). Visual comparison of Figure 4 (right) to Figure 2 (right) indicates there is sigificantly more detail in the high-level approach. Unfortunately, we did not have sufficient time to complete an accuracy analysis of either classification. We strongly believe the higher-level classification ought to be the most accurate approach, and believe further investigation to verify this concept is warranted.
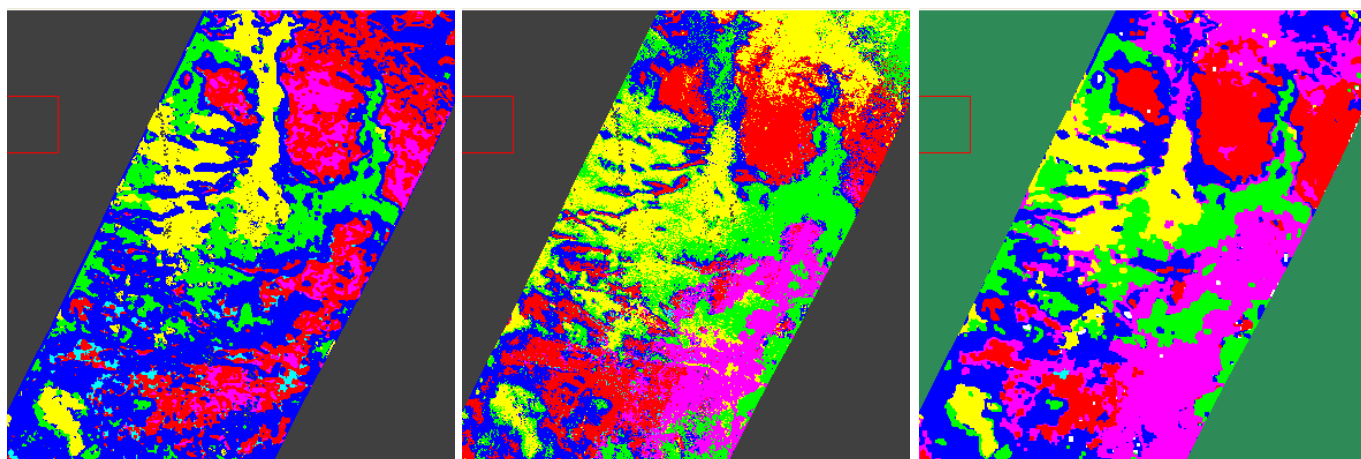
Figure 4. Blob-level classification for SHOALS (left), CASI(center), and Dempster-Shafer decision level fusion (right) – for the Lake Huron dataset.

In Table 1, we summarize the 3 datasets used in this research. Two were collected using CLUBS funding. We have organized these data to support future research and distributed these data to various personnel from the U.S. Navy.

July 2005 Fort Lauderdale	November 2006 Looe Key	August 2007 Lake Huron
SHOALS 3000 + Casi-1500	SHOALS 1000 + Casi-2	SHOALS 1000 + Casi-1500
DiveSpec	DiveSpec	DiveSpec
ASD, AC-9, HydroScat	ASD, AC-9, AC-S, EcoVSF3	ASD, AC-9, EcoBB9, Microprofiler, USB-2000, HPLC

Table 1. Datasets used in the CLUBS Project

IMPACT/APPLICATIONS

Research completed in CLUBS has lead to significant improvement in the quality of seafloor reflectance images generated from SHOALS data. The accuracy of the reflectance estimates in the images depends on the depth of the water. The most accurate estimates are achieved in depths from 6m to extinction (typically 30 m). These accuracies compare to diver-measured values within 10%. Accuracy in shallower waters degrades because of inaccuracies in the estimation of water column attenuation. However, these lesser accurate, shallow water pixels can still be combined with the deeper water estimates to generate a complete image useful for seafloor classification.

A significant improvement realized in this phase of the project was to extend the seafloor imaging onto the beach to create a seamless topo/bathy reflectance image. This type of imagery should have wide utility for shoreline mapping and analysis, including support for antimine warfare applications.

Over the duration of the project, we have shown definitively that SHOALS reflectance and depth data can be used to achieve seafloor classifications better than 85% accuracy. We have only shown this over a limited range of geomorphologies (3 datasets), and we strongly recommend continued research to understand its potential in a wider range of coastal types.

We have shown the combination of passive data with the SHOALS data leads to a small improvement in seafloor classification accuracy, but a large and significant improvement in the ability to characterize the water column. Unfortunately, we did not have sufficient time to fully study this potential and to characterize the accuracy of water column characterizations. Still, the potential demonstrated here fully justifies further research into the development of active/passive data fusion approaches and continuation of the work initiated in this project.

The datasets generated in this work are rare and extremely valuable. We believe the approach adopted in this work, wherein the personnel responsible for the airborne data collections were given full control of the insitu deployments was very successful. Management of the overall insitu effort through the use of sub-contracts yielded high-quality data.

TRANSITIONS

We will attempt to commercialize the REA processor and to promulgate its use for a wide range of benthic mapping applications. For the past year, the Joint Airborne Lidar Bathymetric Technical Center of Expertise (JALBTCX) has served as a beta test site for this software.

The basic funtionality of the algorithms will be adopted into the Coastal Zone Mapping and Imaging Lidar (CZMIL) to be built by Optech at its offices in Kiln, Mississippi.

RELATED PROJECTS

(1) Coastal Zone Mapping and Imaging Lidar (CZMIL). CZMIL is a strategic partnership between Optech International and the Department of Marine Science at the University of Southern Mississippi leading to the design and construction of a next generation bathymetric lidar to improve performance in shallow water, and achieve water column and seafloor characterizations. The CZMIL project will also establish an industry/government/academic center of expertise for bathymetric lidar.

(2) *High-level Data Fusion Software for SHOALS-1000TH. A* National Ocean Partnership Program (NOPP) partnership between Optech International and the Department of Marine Science at the University of Southern Mississippi which addresses theoretical aspects associated with how to best combine data from multiple sensors, extend data fusion onto the beach environment, and collected in situ measurements to support characterization of the water column.

REFERENCES